Remote Seabed Sediment Classification and Sediment Property Estimation Using High Resolution Refection Profiles

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LONG TERM GOALS

The long term research objective is to develop a cost effective technique for mapping the top 20 meters of sediment properties using acoustic remote sensing. In previous years, a chirp sonar was developed to provide quantitative, wideband reflection measurements of the seabed with a vertical resolution of 10 cm. Fuzzy logic techniques have been used to automatically detect subsurface layer interfaces and to find the boundaries between sediment layers. Signal processing techniques were developed to estimate vertical profiles of impedance and attenuation. The procedures for remotely estimating sediment properties are being verified using core data and insitu measurements. New signal processing techniques have been developed that allow several sources transmitting simultaneously in different bands to build a wideband FM pulse in the far field. That wideband data is being used to improve the accuracy of the measuring sediment properties including impedance, attenuation and phase dispersion.

OBJECTIVES

1) Lower the operating frequency band of the chirp sonar below the porous solid cutoff frequency to enable better estimates of sediment properties. The expanded operating band of 500 Hz to 15 kHz is expected to allow reflection measurements below the lower cutoff frequency predicted by the Biot model for most sediments types thereby allowing reflection coefficient measurements in the frequency region where the reflection coefficient provides a good estimate of sediment porosity since grain size and permeability do not significantly affect the reflection coefficient below the cutoff frequency.

2) Conduct at sea experiments using the chirp sonar and collected core samples to compare predicted and measured porosity of surficial sediments and to determine the accuracy of the measurements.

APPROACH

Developing and constructing a low frequency projector and interfacing the projector with the chirp sonar will reduce the lower end of the chirp sonar operating band from 1500 Hz to 500 Hz. The chirp sonar using multiband technology will be able to collect normal incidence reflection data over a band of 1 to 15 kHz while the towed vehicle emulates a point acoustic source. The point source is emulated using 2 piston sources that operate over different but overlapping frequency bands. Each single piston source has a wide beamwidth (greater than 40 degrees) over its band of operation. Multiple transducers can be driven simultaneously with chirp pulses with different bands to generate the wideband chirp pulse in the water that appears (in the far field) to emanate from a point acoustic source. Multiple

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14. ABSTRACT
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rectangular receiving arrays of various sizes are used to control receiving beamwidth and scattering by spatial filtering. The bandwidth of the sonar provides subsurface imagery with 10 cm of vertical resolution. The enhanced bandwidth also improves the accuracy of attenuation and phase measurements needed for impedance inversion and dispersion measurements.

Biot theory and a limited set of field studies have shown that phase dispersion, attenuation and the reflection coefficient (parameters measured by the chirp sonar) are frequency dependent. Below the cutoff frequency of those functions, the porosity predominantly controls the amplitude of the parameters. Above the cutoff frequency, permeability, grain size and porosity drive the values of the acoustic properties and the effect of each property cannot be separated. One must measure the acoustic properties below the cutoff frequency to estimate the porosity. Estimation of the cutoff off frequency and comparisons with measurements above the cutoff frequency may reduce errors in predicting grain size and permeability.

After considering several transducer technologies, we selected a flexural transducer design for the low frequency projector. The flexural disk is a tri-laminar disk consisting of two ceramic disks glued to a metal disk. The full ocean depth configuration will use a rigid Helmholtz resonator to reduce the acoustic short circuit between the sides of the plate. The shallow configuration will be air-backed. The transducer parts were designed using the equivalent circuit approach with a target operating band of 500 Hz to 2 kHz.

Dr. Schock supervises the research program including undergraduate students and at sea experiments.. Jim Wulf is the lead engineer on the project for expanding the sonar bandwidth.

WORK COMPLETED

During the past year, the shallow water configuration of the low frequency projector was designed, constructed and tested. A calibration still needs to be performed to confirm predicted performance.

RESULTS

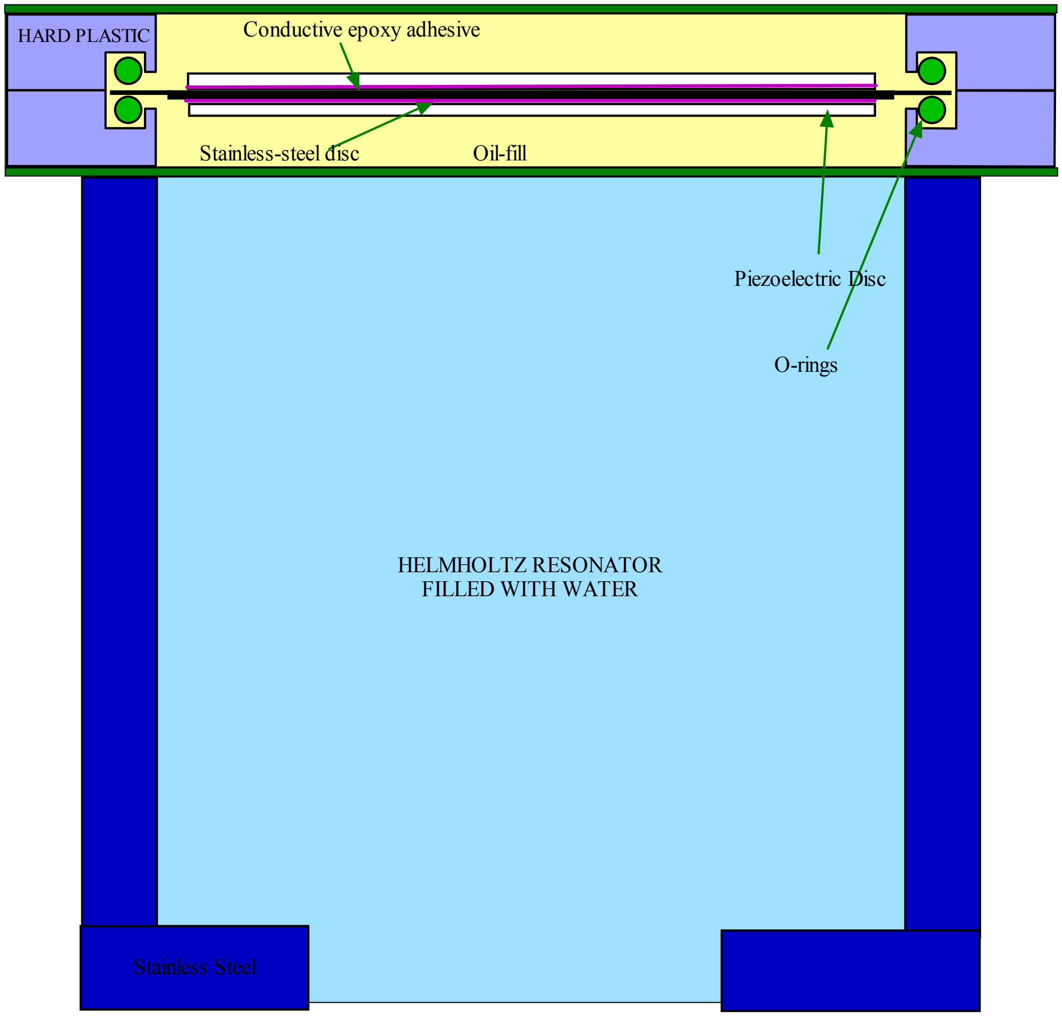
The design of the flexural disk configurations for full ocean depth and shallow operation are shown in Figure 1.

The shallow water transducer configuration has been constructed and tank tested. Preliminary results show that the transducer meets the design specification. A calibration in a deep water test facility is needed to confirm the prelimary measurements that were made in a small acoustic test tank..

IMPACT/APPLICATIONS

Instrumentation and sediment classification procedures have been developed to predict the acoustic and physical properties of the seabed using normal incidence reflection data collected by FM subbottom profilers. This development provides a cost effective method of surveying the top 20 meters of the seabed and obtaining vertical profiles of attenuation and acoustic impedance. From these acoustic properties, physical properties such as bulk density, grain size, and porosity can be estimated.

FULL OCEAN DEPTH CONFIGURATION



SHALLOW WATER CONFIGURATION

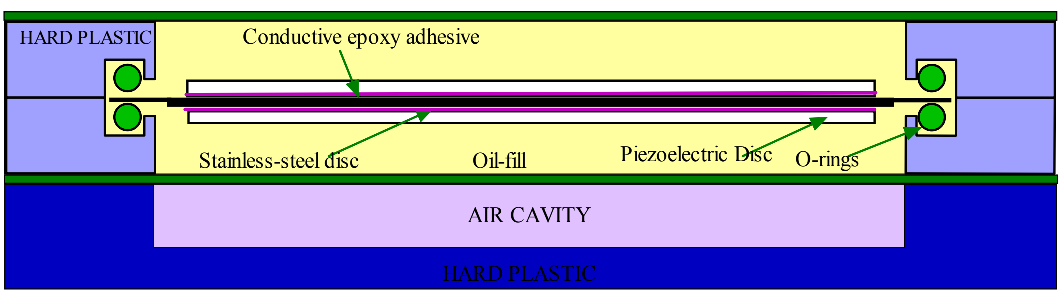


Figure 1. Diagram of deep water and shallow water configurations of flexural disk transducers showing the tri-laminar disk piezo-ceramic source.

TRANSITIONS

The chirp sonar, which evolved out of this program, was transitioned to industry in the early 1990s and has become the standard ocean industry instrument for conducting high resolution ocean surveys. Edgetech, Inc. is manufacturing multi-band chirp sonars, technology derived from this ONR research project.

RELATED PROJECTS

"Remote Sediment Property Estimation From Chirp Data Collected During ASIAEX," ONR G&G Grant. The chirp sonar is being used to remotely predict sediment properties in the East and South China Seas using the same techniques as described in this report.

PUBLICATIONS

1. "Comparison of sound speed and attenuation measured in a sandy sediment to predictions based on the Biot theory of porous media," Kevin L. Williams, Darrell R. Jackson, Eric I. Thorsos, Dajun Tang, Steven G. Schock, IEEE J. of Oceanic Eng (in print)